Shahrjerdi et al. *Studies in Medical Sciences* (2025) 36(3):209-218
https://doi.org/10.61882/umj.36.3.209
Studies is Medical Sciences

ORIGINAL RESEARCH ARTICLE

The Effect of Corrective Exercises and Swing Training on Pain and Pulmonary Function in Women with Kyphosis Deformity

Shahnaz Shahrjerdi[1], Fatemeh Omidi[1], Zahra Geramipour[1]

Published: 27 September 2025
© *The Author(s) 2025*

Abstract

Background Kyphosis is a postural condition characterized by an excessive thoracic spinal curve that leads to a rounded-back posture. Previous studies have indicated that spinal postural abnormalities are associated with alterations in lung volumes. The present study aimed to examine the effects of corrective exercises and swing training on pain and pulmonary function in women with kyphosis.

Methods This semi-experimental study was conducted on 43 women with kyphosis. Participants were randomly assigned to three groups: a control group, a swing training group, and a combined group (corrective exercises plus swing training). The Cobb angle was measured using a flexible ruler, pain was assessed using the Visual Analog Scale, and pulmonary parameters (FEV1, FVC, and FEV1/FVC) were evaluated using spirometry at the pre-test and post-test stages. Training groups exercised for 8 weeks, with three sessions per week, each lasting 45 to 60 minutes. The control group continued their routine daily activities. Data were analyzed using one-way ANOVA and the Bonferroni post-hoc test.

Results The findings showed that both corrective and swing exercises significantly reduced the Cobb angle and back pain and improved pulmonary indices, including FVC and FEV1/FVC ($p < 0.01$). Between-group comparisons indicated that swing training produced the most significant reduction in the Cobb angle ($p < 0.05$). Additionally, the combined group, which performed both types of exercises, demonstrated superior improvements in back pain and in FVC and FEV1/FVC compared with the other groups ($p < 0.05$).

Conclusion All three interventions were effective in improving the examined variables, though their effectiveness varied. The combined approach appears to offer greater benefits for individuals with kyphosis, contributing to more comprehensive improvements. Therefore, incorporating both corrective exercises and swing training may be considered an effective therapeutic strategy for enhancing the condition of individuals with kyphosis.

Keywords Cobb Angle, Corrective Exercises, Kyphosis, Pulmonary Function, Swing Training

✉ hShahnaz Shahrjerdi
s-shahrjerdi@araku.ac.ir

1. Department of Sport Physiology and Sport Injuries, Faculty of Physical Education and Sport Sciences, Arak University, Arak, Iran

Received: 25 Aprill2025 / Revised: 8 July 2025 / Accepted: 5 September 2025

1 Introduction

Maintaining proper postural alignment is considered an important indicator of overall health. Poor habits in sitting, standing, walking, carrying objects, inappropriate clothing, occupational factors, heredity, illnesses, and anthropometric characteristics can impair growth and lead to postural abnormalities. These deviations not only disrupt optimal posture but may also cause dysfunction in other systems, such as the cardiovascular and respiratory systems, as well as various types of pain.[1]

Kyphosis is regarded as one of the most common postural deformities. Researchers consider any increase beyond the normal thoracic curvature (45 degrees) as an indication of this condition.[2] An increased kyphotic posture results in a rounded-back appearance. Evidence shows a significant relationship between various spinal postural abnormalities and changes in lung volumes. Individuals with a rounded thoracic posture demonstrate lower lung capacities and ventilatory volumes than those with normal posture.[3]

Lung capacities include vital capacity, functional residual capacity, and total lung capacity. In pulmonary functional assessments, forced vital capacity (FVC), which is the amount of air expelled from the lungs following a deep inhalation and a forceful exhalation, and forced expiratory volume in one second (FEV1), which is the fraction of the vital capacity expelled during the first second of a forceful exhalation, are commonly measured. In healthy individuals, FEV1 typically accounts for 75–80% of the FVC and reflects airflow in the larger airways. Since FEV1 alone represents a raw value, it is commonly expressed as a percentage of FVC.[4]

Kyphosis is one of the most prevalent postural abnormalities and a major factor contributing to upper-body pathology. Clinicians often manage affected individuals by prescribing standard corrective exercises based on Kendall's theories. Thoracic spinal deformities can lead to pain and functional impairments throughout life.[5] Kyphosis may result from factors such as disc compression, vertebral fractures, osteoporosis, Scheuermann's disease, and weakness of the extensor muscles of the spine. Genetic predisposition and poor postural habits, particularly in shy or tall individuals, also play a role. This deformity is associated with complications such as impaired motor and pulmonary function, increased risk of vertebral fractures, reduced chest expansion, and limited upper-limb mobility. Research evidence shows reduced respiratory indices in affected individuals, and the prevalence of postural abnormalities in Iran, especially among young adults, is increasing.[2]

For the correction of thoracic kyphosis, several approaches, such as manual therapy, postural re-education, taping, orthoses, and exercise therapy, are commonly used. In postural kyphosis, corrective exercises serve as the primary intervention. Various researchers, including Goodarzi, Hamidiyeh, and Roshani, have examined these methods, and training modalities such as Pilates, TRX, and the NASM approach have also been applied in studies aimed at improving kyphosis.[6,7]

Bodyweight resistance exercises performed under unstable conditions combine open- and closed-chain movements and can simultaneously enhance balance, flexibility, and strength. One of the commonly used tools in this domain is the swing, which consists of a padded hammock and six reinforced fabric handles, enabling exercises in semi-suspended or fully suspended positions. This device is widely employed in rehabilitation, correction of structural disorders, inversion therapy, and physical activity, and supports the body safely while allowing movement on an unstable surface.[8]

Inversion and anti-gravity exercises have a long history that spans thousands of years; the novelty lies in today's modern equipment and updated methods. By suspending the body in space, these exercises reduce the influence of gravity and provide multiple benefits. In disciplines such as yoga, Pilates, and TRX, the requirement to maintain balance while suspended substantially increases muscular engagement and the body's demand for stability. This condition also enhances flexibility and enlarges the range of motion in joints. In medical settings, suspension and inversion techniques can reduce spinal loading, improve blood circulation, and create deep stretches that relieve back and neck pain and decrease muscular tension.[8]

Given the extensive research on corrective training for kyphosis, particularly TRX, which is a form of suspension training, and considering that swing exercises also fall within the category of suspended training, it becomes increasingly important to examine the effects of such exercises on musculoskeletal abnormalities. To date, only one study in Iran has investigated swing exercises, focusing on balance in patients with multiple sclerosis. As such, research on the use of swing training to correct kyphosis remains lacking. Therefore, the present study seeks to answer the following question: What effects do corrective exercises and swing training have on pain and pulmonary function in women with kyphosis?

2 Methods

Study Design and Participants

This study employed a quasi-experimental design with a pretest–posttest format and included experimental and control groups. The study population consisted of all women diagnosed with kyphosis. From this population, 45 women aged 20 to 50 years with kyphosis greater than 45° were purposefully selected and randomly assigned using Randlist software into three groups: Swing group (n = 15), Corrective Exercises + Swing group (n = 15), and Control group (n = 15). Sample size estimation was performed using G*Power software with a significance level of 0.05 and a statistical power of 0.85. During the study, two participants withdrew, reducing the sample size to 43; however, statistical power remained acceptable (> 0.8), ensuring the validity of the results.

Inclusion Criteria were women aged 20–50 years with kyphosis exceeding 45° and the presence of back pain in addition to kyphosis. Exclusion Criteria were a history of fractures, dislocations, osteoarthritis, or other spinal orthopedic problems, a history of surgery, abnormal pain experienced during testing, inadequate cooperation during tests, or a lack of willingness to continue participation. All participants provided written informed consent voluntarily before participation.

Intervention Protocol

Exercise protocols for the Swing and Corrective Exercises + Swing groups were conducted over 8 weeks, with three sessions per week, each lasting 45–60 minutes. The Control group maintained their usual lifestyle without any intervention. Each session began with 10 minutes of warm-up exercises, including stretching, followed by 40 minutes of group-specific exercises (corrective exercises and swing exercises for one group, swing exercises only for the other). Sessions concluded with 10 minutes of cool-down exercises. During the sessions, the researcher monitored participants to ensure correct body posture and joint angles.

Posttest measurements were conducted 48 hours after completing the training program under conditions similar to those of the pretest and were compared with pretest values and with those of the other groups.

Measurement Tools

VAS for Pain

Pain intensity was assessed by the researcher using the VAS, a standardized tool ranging from 0 to 10. The content validity of this instrument has been confirmed by a panel of physiotherapy and corrective exercise specialists. Its reliability and validity are excellent, with an intraclass correlation coefficient (ICC) of 0.91, indicating high measurement consistency.[9]

Flexible Ruler for Kyphosis Measurement

Thoracic kyphosis was measured pre- and post-intervention using a flexible ruler approximately 60 cm long, consisting of a narrow metal strip coated with plastic. The ruler can be bent in a single plane and retains its shape to a large extent.[3]

Participants were asked to remove upper-body clothing so that the researcher could palpate the spine and identify the second thoracic (T2) and twelfth thoracic (T12) vertebrae. To locate T2, the participant stood with the head slightly flexed forward. The most prominent vertebra, C7, was identified, and T2 was marked two vertebrae below it. To locate T12, participants placed their hands on a table, leaned slightly forward, and shifted their weight onto their hands. The researcher palpated the twelfth rib on both sides with the thumbs, tracing it upward and inward until it disappeared into the soft tissue. A straight line connecting the tips of the thumbs indicated the location of the T12 spinous process.

All measurements were taken with participants standing in a relaxed posture, feet evenly balanced, and looking forward. The flexible ruler was then molded along the spine to conform to its curvature, ensuring no gaps. The marked points were transferred onto the ruler, and the ruler was carefully removed and placed on paper. The curvature was traced, and the points were marked on the drawing. The distance between points (L) and the depth of the curve (H) were measured with the ruler, and these values were used in Formula 1 to calculate the kyphosis angle. Angles greater than 45° were considered indicative of kyphosis.[4]

The validity of this method has been confirmed by comparison with radiographic measurements, showing a high correlation (r = 0.91). Intra-rater and inter-rater reliability were 0.89, 0.92, and 0.82, respectively, indicating excellent reproducibility in measuring thoracic curvature.[10]

Spirometry

Lung capacity was measured using a spirometer, also referred to as a respirometer. Today, lung capacity can also be assessed using a plethysmograph. The spirometer consists of two chambers: an outer chamber (water chamber) and an inner chamber. The outer chamber is filled with water, while a floating drum is inverted and immersed in the water. Equilibrium is maintained by a weight attached to the top of the inverted drum via a string or chain. A pen connected to the counterweight records the drum's movement on a calibrated recording sheet.

The inner chamber is inverted and contains a small hole at the top. A long metal tube passes through the inner chamber from bottom to top, exiting through the hole and extending into the water in the outer chamber above the water surface. A rubber tube is attached to the outer end of the metal tube, and a mouthpiece is connected to the other end of the rubber tube. Participants perform oral breathing while their nose is clipped. During exhalation, the drum rises, and the counterweight descends; during inhalation, the drum lowers, and the counterweight rises. These vertical movements are recorded as a graph, with upward deflections indicating inhalation and downward deflections indicating exhalation.

The spirometer is designed for single-breath measurements. Its face and content validity have been confirmed in sports physiology and respiratory studies, and its reliability has been reported above 0.85 in similar studies, indicating adequate accuracy and reproducibility for measuring lung capacity.[11]

Grid Board

The grid board consists of a wooden or metal frame with thin longitudinal and transverse strings spaced 10 cm apart, forming squares with 10 cm sides. The overall frame measures 100 × 200 cm. To assess postural abnormalities, the participant stands behind the grid board, while the examiner stands 3 m in front of it. The examiner uses the central red line of the grid as a reference and evaluates the alignment of specific body parts relative to it.

Participants wear minimal clothing, no shoes or socks, and stand comfortably in a designated position. A point approximately 45 cm behind the grid, aligned perpendicularly to the grid's central vertical line, marks the participant's center of gravity. The participant's inner ankles are positioned 4 cm from this point. The researcher stands approximately 3–4 m from the grid, aligned with the central vertical line and the participant.

The examiner instructs the participant to adjust their body into three or four positions aligned with the vertical line. Observations are made from different angles and recorded according to the nearest observed body posture, cross-referenced with the New York test. The content validity of this tool has been confirmed by a panel of ergonomics and corrective exercise specialists. Observer reliability with the New York test has been reported as 0.83, indicating acceptable stability in postural assessment using this method.[12]

The following tables summarize the exercise protocols used in this study. Table 1 presents the swing exercise protocol, and Table 2 shows the corrective exercise protocol combined with swing, including exercise type, duration, and frequency.

Table 1 Swing training protocol

Repetitions/duration	Number of sets	Exercise	Week
10	3	Stretching and hunching of the thoracic back muscles. Forward stretching of the back muscles.	Week 1
10	3	Perform the exercises from the previous week, in addition to the new exercises: Side incline position Positioning under the apparatus, placing the swing on the back muscles, and allowing suspension.	Week 2
10	3	Perform the exercises from the previous week, in addition to the new exercises: Hands behind the back, grasp the straps, and assume an inclined position. From the hip area, position on the swing, lift the legs to mid-pelvis, and hold the medium handles with the hands.	Week 3
10	3	Perform the exercises from the previous week.	Week 4
20	3	Perform the exercises from the previous week, in addition to the new exercises: Stand one meter in front of the apparatus, grasp the swing straps with hands at a comfortable distance, and move up and down.	Week 5
30	3	Perform the exercises from the previous week, in addition to the new exercises: Stand sideways at a distance from the apparatus, keep one hand stationary, and move the other hand forward and backward from the side.	Week 6
30	3	Perform the exercises from the previous week, in addition to the new exercises: Stand in front of the apparatus at a distance, grasp the medium handles, lean slightly forward, and perform lateral arm openings and closings. Bend over the swing from the hip area.	Week 7
30	3	Repeat the exercises following the previous week's routine.	Week 8

Table 2 Corrective exercise protocol combined with swing

Repetitions/duration	Number of sets	Exercise	Week
10	3	T Exercise W Exercise Interlock the hands behind the body, move them away from the back, and lift and lower them. Bend over the swing from the hip area and tuck the legs toward the abdomen.	Week 1
10	3	Side inclined position. Position under the apparatus, place the swing on the back muscles, and suspend the body.	Week 2
10	3	Continue the exercises from the previous week and add the new exercises: Lie on the stomach, spread the arms sideways, and lift and lower them along the sides. Position under the apparatus, place the swing on the back muscles, and allow suspension.	Week 3
10	3	Continue the exercises from the previous week and add the new exercises: Place a full roller under the posterior chest muscles and roll it up and down. Perform forward stretching of the back muscles.	Week 4
20	3	Repeat the exercises from the previous week, increasing repetitions to 30.	Week 5
30	3	Repeat the exercises from the previous week and add the new exercise: Place the hands on the wall and bring the chest closer to the wall. Stand at a distance in front of the apparatus, grasp the medium handles, lean slightly forward, and perform lateral arm openings and closings.	Week 6
30	3	Repeat the exercises following the previous week's protocol.	Week 7
30	3	Repeat the exercises following the previous week's protocol.	Week 8

For data analysis, descriptive statistics, such as the mean and standard deviation, were used. Inferential statistics included the Shapiro–Wilk test to assess the normality of data distribution, the paired t-test to examine within-group differences, and one-way ANOVA to evaluate between-group differences. In cases of significant differences, the Bonferroni post hoc test was applied. All statistical analyses were performed using SPSS version 26, with a significance level set at ($p \leq 0.05$). Graphs were created using GraphPad PRISM
Version 9.

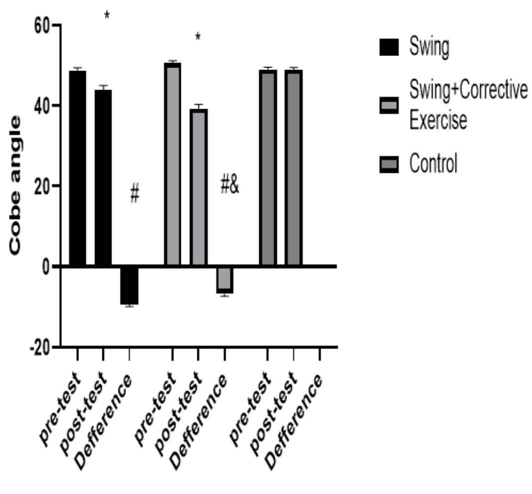
3 Results

As observed, the descriptive indices of the participants' demographic variables are presented separately in Table 3.
The normality of data distribution was assessed using the Shapiro–Wilk test, and group homogeneity was evaluated using Levene's test. Between-group differences were analyzed using one-way ANOVA, and in cases of significant differences, the Bonferroni post hoc test was applied. Within-group comparisons were conducted using the paired t-test. The results of the one-way ANOVA for between-group differences and the paired t-test for within-group comparisons of pain perception scores, Cobb angle, FVC, and FEV1/FVC are presented in Figure 1.

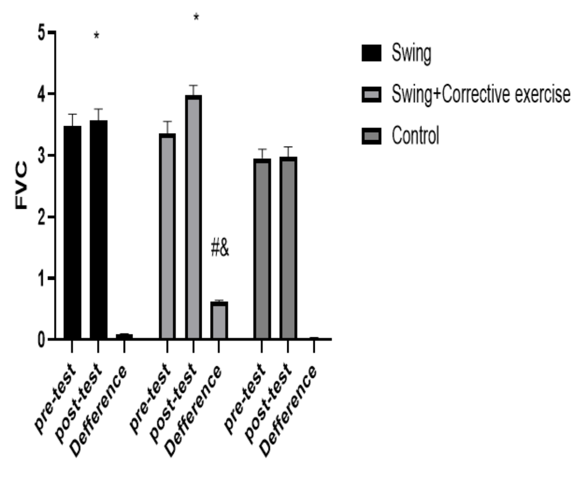
The results of the one-way ANOVA and paired t-test indicate that back pain, Cobb angle, FVC, and FEV1/FVC showed significant differences after the intervention ($p \leq 0.05$). In other words, the effectiveness of swing exercises and the combined swing with corrective exercises in reducing back pain, correcting the kyphosis angle, and increasing FVC and FEV1/FVC in women with kyphosis deformity is confirmed.

Table 3 Demographic information

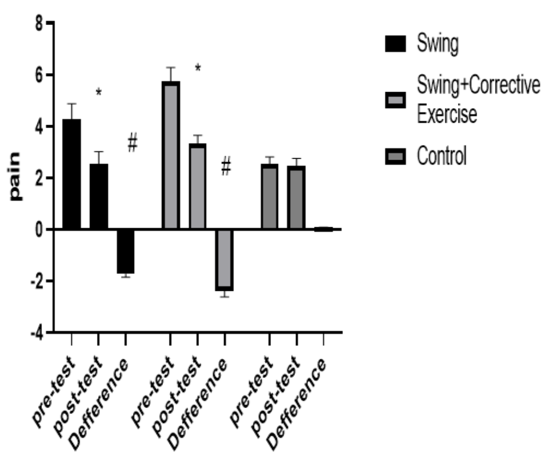
P-value	Control group	Swing + corrective exercise group	Swing group	Variable
0.654	2.39 ± 31.91	1.54 ± 29.75	2.30 ± 27.25	Age (years)
0.845	8.04 ± 165.75	6.78 ± 165.66	7.67 ± 166.33	Height (cm)
0.296	1.39 ± 61.34	4.03 ± 60.56	3.49 ± 59.66	Weight (kg)
0.49	1.38 ± 22.35	1.99 ± 22.13	1.94 ± 21.65	Body mass index (kg/m²)



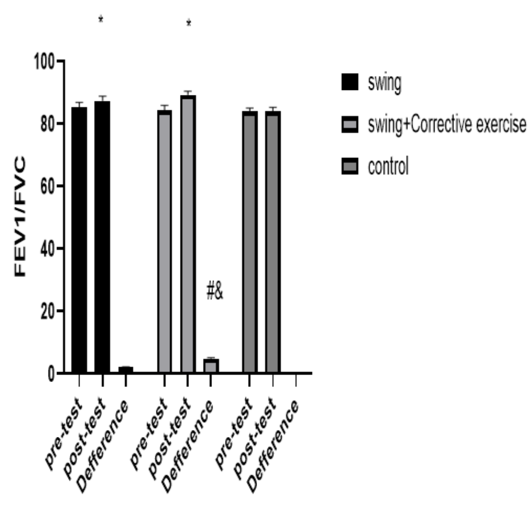
Cobb Angle



FVC



VAS/Pain



FEV1/FVC

Figure 1 Within-group comparisons of back pain perception scores, Cobb angle, FVC, and FEV1/FVC

4 Discussion

The present study aimed to investigate the effects of corrective exercises and swing training on pain, Cobb angle, and pulmonary function in women with kyphosis. The results showed that all three interventions led to a significant reduction in Cobb angle, with swing exercises demonstrating greater effectiveness. These findings are consistent with those of Dudoniene et al., who reported that swing exercises were more effective than conventional corrective exercises in reducing pain, improving Cobb angle, and enhancing trunk muscle endurance.[13] Similarly, Park et al. found that combined exercises positively influenced spinal alignment and balance.[14] Sepehri et al. also reported the beneficial role of swinging exercises on patient function.[15] However, Ko et al. reported that although lumbar stabilization and sling exercises improve strength and flexibility, they do not significantly affect the Cobb angle.[16] This discrepancy may be attributed to postural changes associated with kyphosis and the resulting muscular imbalances, a mechanism also highlighted by Sidi et al. in similar studies.[17]

In the present study, a significant reduction in Cobb angle was observed, which aligns with the findings of Vaughn and Brown regarding the effects of Schroth exercises on spinal curvature improvement.[18] Therefore, the results indicate that a combined exercise program, including stretching, strengthening, and Schroth exercises, improves postural alignment awareness, corrects muscular imbalances, and positively affects kyphosis.[19] Swing exercises, through three-dimensional and multiplanar movements, more effectively stimulate deep joint and muscle receptors. Kim et al. demonstrated that such multidimensional stimulation enhances proprioception and neuromuscular control.[20] Additionally, Li et al. reported that swing exercises facilitate deep stabilizer muscle activity by stimulating mechanoreceptors, which play a critical role in spinal alignment control. One reason for the greater effectiveness of swing exercises may be their influence on the fascial system.[21]

Schleip and Müller reported that multiplanar dynamic movements promote fascial tissue remodeling and flexibility, which may improve force transmission along kinetic chains and correct spinal alignment.[22] Studies have shown that swing exercises, by creating controlled instability, simultaneously activate deep and superficial trunk muscles. Unlike traditional corrective exercises that often target specific muscles, this activation pattern promotes more comprehensive muscular strengthening. Dynamic exercises in unstable environments are more effective in enhancing stabilizer muscle strength and endurance.[15,23] Furthermore, swing exercises, by generating controlled movements across various ranges, more effectively increase flexibility and range of motion. This improved mobility, combined with maintained dynamic stability, can contribute to more effective Cobb angle correction. The greater efficacy of swing exercises in reducing Cobb angle can be attributed to multiple factors: multidimensional neuromuscular stimulation, improved motor control, effects on the fascial system, and functional movement challenges. These findings can inform the design of more effective therapeutic protocols for individuals with kyphosis.[24]

The present study also showed that eight weeks of corrective exercises and swing training led to significant reductions in back pain among women with kyphosis. All three interventions produced meaningful pain reduction, with the combination of swing and corrective exercises yielding the most significant decrease. These results are consistent with previous studies reporting that swing, sling, and similar exercises positively impact low back pain in spinal deformities.[20] Kim et al. observed significant reductions in sway area, sway length, and sway velocity in the lumbar region. Reductions in sway parameters were greater in the swing group under dynamic conditions, reflecting the need for greater balance recovery. This suggests that lumbar swing exercises using the Neuro-Sc chain reduce pain, enhance proprioceptive-motor function, and activate neural roots, thereby improving postural control.[20,25]

Rehabilitation programs targeting neural root activation through the Neuro-Sc chain reduce pain, activate global and deep muscles, and enhance lumbar muscle strength.[26] Shumway-Cook and Woollacott observed increased muscle activity when exercises were performed on an unstable support base. Strengthening deep muscles activates predictive postural control mechanisms, improving movement stability.[27] Suspended exercises using the Neuro-Sc method enhance neural root activation, smooth trunk-hip coordination, and reduce abnormal flexion-relaxation patterns. Lumbar stabilization exercises using the Neuro-Sc sling positively influence muscle responses and predictive postural control.[28]

Corrective exercises also contribute to spinal alignment by strengthening back extensors and stretching shortened anterior muscles.[29,30] The dynamic movements involved in swing exercises increase local blood flow, improving nutrient delivery to intervertebral discs and surrounding tissues, which aids tissue repair and regeneration. Additionally, the exercises influence the limbic system and reduce anxiety. Regular exercise increases endorphin release, improving mood and reducing anxiety, which can help break the pain-spasm-pain cycle.[23] Moreover, swing and sling exercises, through controlled stability challenges, strengthen the motor control system, enhancing neuromuscular coordination and movement patterns.

Finally, combining corrective and swing-sling exercises produces a synergistic effect. Corrective exercises improve skeletal alignment and muscular balance, providing a foundation for the enhanced effectiveness of swing exercises. The efficacy of this combination in reducing back pain in individuals with kyphosis arises from multiple complex mechanisms, including improved neuromuscular control, postural correction, increased strength and flexibility, enhanced circulation, and psychoneurological benefits. Understanding these mechanisms can guide the development of optimized therapeutic protocols.[24]

Pulmonary Function Results

The results related to pulmonary function indicated that FVC and the FVC/FEV1 ratio improved following the intervention. These findings align with those of Eftekhari et al., who reported that corrective exercises positively affect chest expansion and respiratory function in individuals with kyphosis.[31] El Gendy et al. also demonstrated that mobilization with movement (MWM) combined with corrective exercises produced greater improvements in pulmonary indices compared to corrective exercises alone.[32] Additionally, Jang et al. reported that thoracic corrective exercises improve kyphosis angle, head posture, and vital capacity.[33]

Kyphosis and pulmonary function are closely linked, as kyphosis can lead to significant respiratory impairments. The literature shows that increased kyphotic angles are associated with reduced lung volumes and respiratory pressures, particularly in older adults, underscoring the importance of monitoring pulmonary function in individuals with kyphosis.[34] Kyphosis primarily results in restrictive lung disease, reducing forced expiratory volume and FVC. Studies also indicate that as kyphosis severity increases, pulmonary function declines, with a notable correlation between Cobb angle and lung volume in older adults.[35] Corrective movements have been shown to significantly improve pulmonary function in kyphotic patients, with positive correlations observed between localized kyphosis correction and enhanced lung volumes and respiratory performance. Clinically, posterior spinal interventions following tuberculous kyphosis have been evaluated for their effect on spinal deformity, guiding thoracic kyphosis management.[36]

In young adults, MWM combined with postural exercises significantly increased FVC and maximal voluntary ventilation compared to control groups.[32] Similarly, older women participating in chest corrective exercises demonstrated marked improvements in thoracic kyphosis and chest function, indicating a positive impact on respiratory health.[33] While both corrective exercises and surgical interventions show promising outcomes in enhancing pulmonary function in hyperkyphotic patients, individual variability in response underscores the need for personalized rehabilitation strategies. Some patients may experience limited improvements, highlighting the importance of tailored exercise programs.

Ishizuka et al. reported that dynamic exercises, such as swing training, enhance intervertebral disc perfusion and the viscoelastic properties of connective tissues, thereby contributing to spinal flexibility and deformability. Swing exercises, by introducing diverse movement challenges, help correct faulty movement patterns and break poor postural habits, promoting proper motor patterns.[36] Additionally, swing exercises engage the vestibular and visual systems, improving postural control and helping maintain correct spinal alignment.[20] Although traditional corrective exercises are effective in improving pulmonary function in kyphotic individuals, they have limitations, including being primarily single-plane and providing less challenge to the motor control system. They may also have limited transferability to functional activities.[15]

The study did not identify which specific exercises among the applied interventions had the most significant impact on outcomes, highlighting the need for further research comparing different functional exercises. Pelvic motion, which is related to thoracic kyphosis, was not measured in this study, leaving a gap in understanding the relationship between pelvic kinematics and spinal alignment. Strengthening exercises were included; however, back muscle strength was not measured, necessitating additional studies to confirm the effect of muscular strength on thoracic angle correction.

5 Conclusion

The findings of this study indicate that all three interventions, corrective exercises, swing exercises, and their combination, were effective in improving the assessed variables, though their relative effectiveness varied. For Cobb angle reduction, swing exercises alone demonstrated greater efficacy, likely due to their multidimensional nature and effects on the neuromuscular and fascial systems. Conversely, the combination of swing and corrective exercises was more effective in reducing back pain and improving pulmonary function indices (FVC and FVC/FEV1 ratio).

These findings suggest that a combined approach may offer multiple benefits, contributing to a comprehensive improvement in patient status. Overall, the study provides valuable evidence regarding the relative effectiveness of various interventions in treating kyphotic deformities and suggests that intervention selection should be based on primary treatment goals and individual patient conditions. When the main goal is Cobb angle reduction, swing exercises may be the preferred option, whereas a combined approach may yield better outcomes for patients experiencing pain and respiratory difficulties.

Declarations

Acknowledgments
We express our sincere gratitude to all participants who assisted us in conducting this study.

Artificial Intelligence Disclosure
No artificial intelligence (AI) tools were used in the writing, analysis, or preparation of this manuscript.

Authors' Contributions
Conceptualization was carried out by Zahra Geramipour and Shahnaz Shahrjerdi. Data curation and investigation were performed by Fatemeh Omidi. Formal analysis was conducted by Shahnaz Shahrjerdi and Fatemeh Omidi. Methodology development involved Zahra Geramipour and Shahnaz Shahrjerdi. Project administration was managed by Shahnaz Shahrjerdi, while resources were provided by Zahra Geramipour. Writing of the original draft was undertaken by Zahra Geramipour and Shahnaz Shahrjerdi, and review and editing were completed by the same authors.

Availability of Data and Materials
The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest
The authors declare that there is no conflict of interest.

Consent for Publication
Not applicable.

Ethical Considerations
This study was approved by the Research Council and the Ethics Committee of Arak University under the Code of Ethics IR.ARAKU.REC.1402.084 and has been registered in the Iranian Registry of Clinical Trials with the Registration Code IRCT20240318061324N1.

Funding
No financial support was received for the present study.

Open Access
This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit https://creativecommons.org/licenses/by-nc/4.0.

References

1. Memari, Jahromi K, Fallahi, El-Islami S. The effect of six weeks of structural and respiratory muscle corrective exercises on cardiac and pulmonary indices of 10-12 year old boys with kyphosis. Quarterly Journal of Rehabilitation Archives. 2017;18(1):51-62. doi: 10.21859/jrehab-180151
2. Culham EG, Jimenez HA, King CE. Thoracic kyphosis, rib mobility, and lung volumes in normal women and women with osteoporosis. Spine (Phila Pa 1976). 1994;19(11):1250-5. doi: 10.1097/00007632-199405310-00010.
3. Lutfi MF. The physiological basis and clinical significance of lung volume measurements. Multidisciplinary respiratory medicine. 2017;12(1):3. doi: 10.1186/s40248-017-0084-5
4. Rajabi, Latifi, Minunjad, Hooman, Rajabi. Investigation of the effect of soft tissues in measuring thoracic kyphosis angle using a flexible ruler. Sports Medicine Studies. 2015;7(18):91-104.
5. Godarzi Salkhori A, Daei R, Faridnia H, Bigtashkhani R. The effect of 8 weeks of Pilates exercises on pain change and kyphosis angle in women's health in Tehran's second district. Journal of Sociology of Lifestyle (SLS). 2022;7(18):190-210.
6. Hamidiyeh M, Naserpour H, Chogan M. Change in Erector Spinae muscle strength and Kyphosis Angle following an eight weeks TRX training in middle-age men. International Journal of Aging Health and Movement 2021;3(1):13-20.
7. Muhtaroglu M, Lafcı Fahrioglu S, Selcuk F, İlgi S. Evaluation of thoracic kyphosis angle and respiratory functions in patients with multiple sclerosis. Annals of Applied Sport Science 2021;9(2). doi: 10.52547/aassjournal.990
8. Khoshyari T, Shodjaedin SS. Pilates and changes in anomaly curvature Postural kypfhosis in girls between 15-18. 2015.
9. Rezaei F. Comparison of 8 Weeks of Selected TRX Training and Weight Training on Improving Motor Function and Chronic Nonspecific Back Pain in Women Aged 35 to 55. Journal of Sport Biomechanics 2024;10(2):104-20. doi: 10.61186/JSportBiomech.10.2.104
10. Ghmari M Rajabi R, Akbarnejad A, Minonejad H. Comparison of thoracic kyphosis and scapular bone positioning in national-level freestyle and Greco-Roman wrestlers with non-athletes. 2011.
11. Jalilian S, Sabzalipour S, Mohammadi Rouzbahani M, Ibrahimy Ghavamabadi L, Rajabzadeh Ghatrami E. Evaluation of Respiratory Parameters of Workers Exposed to BTEX Compounds in an Oil Refining Company. Journal of Research in Environmental Health 2024;10(2):36-47.
12. Farahani R, Norasteh A, Fadaei Dehcheshmeh M. Study of the prevalence of posture disorders in rural women based on age group and body mass index in Markazi Province. 2023. doi: 10.32598/SJRM.12.2.4
13. Dudoniene V, Kuisma R, Juodzbaliene V. Sling suspension therapy is an effective treatment method of juvenile spinal osteochondrosis in adolescent girls. J Back and Musculoskelet Rehabil 2022;35(4):873-9. doi: 10.3233/BMR-210099
14. Park Y-J, Kim W-M, Yu J-H, Moon H-H, Seo Y-G. Effects of combined exercise program on spinal curvature and balance ability in adolescents with kyphosis. Children(Basel) 2022;9(12):1999. doi: 10.3390/children9121999
15. Sepehri Far S, Sahebozamani M, Ebrahimi H. Effects of 8 Weeks Antigravity Swing Exercise on Functional Ability of Walking and Upper Body in Multiple Sclerosis Women with Moderate Disability. Journal of Paramedical Sciences & Rehabilitation. 2022;11(1):28-36.
16. Ko KJ, Ha GC, Yook YS, Kang SJ. Effects of 12-week lumbar stabilization exercise and sling exercise on lumbosacral region angle, lumbar muscle strength, and pain scale of patients with chronic low back pain. J Phys Ther Sci 2018;30(1):18-22. doi: 10.1589/jpts.30.18

17. Seidi F, Rajabi R, Ebrahimi I, Alizadeh MH, Minoonejad H. The efficiency of corrective exercise interventions on thoracic hyperkyphosis angle. J Back Musculoskelet Rehabil. 2014;27(1):7-16. doi: 10.3233/BMR-130411

18. Vaughn DW, Brown EW. The influence of an in-home based therapeutic exercise program on thoracic kyphosis angles. J Back Musculoskelet Rehabil. 2007;20(4):155-65. doi: 10.3233/BMR-2007-20404

19. Kuru T, Yeldan İ, Dereli EE, Özdinçler AR, Dikici F, Çolak İ. The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical trial. Clin Rehabil 2016;30(2):181-90. doi: 10.1177/0269215515575745

20. Kim JH, Kim YE, Bae SH, Kim KY. The effect of the neurac sling exercise on postural balance adjustment and muscular response patterns in chronic low back pain patients. J Phys Ther Sci. 2013;25(8):1015-9. doi: 10.1589/jpts.25.1015

21. Li X, Xu G, Li L, Hao Z, Lo WLA, Wang C. Analysis of muscle synergies and muscle network in sling exercise rehabilitation technique. Comput Biol Med. 2024;183:109166. doi: 10.1016/j.compbiomed.2024.109166

22. Schleip R, Müller DG. Training principles for fascial connective tissues: scientific foundation and suggested practical applications. J Bodyw Mov Ther. 2013;17(1):103-15. doi: 10.1016/j.jbmt.2012.06.007

23. Yan Z-W, Yang Z, Zhao F-L, Gao Y, Wu Z-K, Wang J-L, et al. Effect of sling exercise therapy on surface electromyography and muscle thickness of superficial cervical muscle groups in female patients with chronic neck pain. Journal of Back and Musculoskeletal Rehabilitation 2023;36(2):387-97. doi: 10.3233/BMR-220030

24. Kirkesola G. Sling exercise therapy (SET): a total concept for exercise and active treatment of musculoskeletal disorders. The Journal of Korean Academy of Orthopedic Manual Physical Therapy 2001;7(1):87-106.

25. Kirkesola G. Neurac-a new treatment method for long-term musculoskeletal pain. J Fysioterapeuten. 2009;76(12):16-25.

26. Leitner C, Mair P, Paul B, Wick F, Mittermaier C, Sycha T, et al. Reliability of posturographic measurements in the assessment of impaired sensorimotor function in chronic low back pain. J Electromyogr Kinesiol. 2009;19(3):380-90. doi: 10.1016/j.jelekin.2007.09.007

27. Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice: Lippincott Williams & Wilkins; 2007. doi: 10.1007/s00198-007-0358-4

28. Berg WP, Strang AJ. The role of electromyography (EMG) in the study of anticipatory postural adjustments. Applications of EMG in Clinical and Sports Medicine. 2012;11:53-68. doi: 10.5772/25388

29. Kim S-Y, Kim T-Y. Theoretical basis and application of the neurac technique which uses the sling exercise therapy. The Journal of Korean Academy of Orthopedic Manual Physical Therapy 2006;12(2):52-65.

30. Chen B-J, Liu T-Y, Wu H-C, Tsai M-W, Wei S-H, Chou L-W. Effects of sling exercises on pain, function, and corticomuscular functional connectivity in individuals with chronic low back pain-preliminary study. Plos One 2023;18(11):e0288405. doi: 10.1371/journal.pone.0288405

31. Eftekhari E, Sheikhhoseini R, Salahzadeh Z, Dadfar M. Effects of telerehabilitation-based respiratory and corrective exercises among older people with thoracic hyper-kyphosis: a clinical trial. BMC geriatr. 2024;24(1):234. doi: 10.1186/s12877-024-04779-8

32. El Gendy MH, Mohamed SR, Taman SE, Hussein HM, Abu El Kasem ST. Short term effect of spinal mobilization with movement (MWM) on pulmonary functions in nonsmokers with thoracic hyperkyphosis: a randomized single-blinded controlled trial. J Man Manip Ther. 2023;31(2):64-71. doi: 10.1080/10669817.2022.2075203

33. Jang H-j, Kim M-j, Kim S-y. Effect of thorax correction exercises on flexed posture and chest function in older women with age-related hyperkyphosis. J Phys Ther Sci. 2015;27(4):1161-4. doi: 10.1589/jpts.27.1161

34. Zeng Y, Chen Z, Ma D, Guo Z, Qi Q, Li W, et al. The influence of kyphosis correction surgery on pulmonary function and thoracic volume. Spine(Phila Pa 1976). 2014;39(21):1777-84. doi: 10.1097/BRS.0000000000000524

35. Vera P, Lorente A, Burgos J, Palacios P, Antón-Rodrigálvarez LM, Tamariz R, et al. Cardiorespiratory function of patients undergoing surgical correction of Scheuermann's hyperkyphosis. Scientific Reports 2021;11(1):20138. DOI: 10.1038/s41598-021-99674-2. DOI: 10.1097/BRS.0000000000000524. doi: 10.1038/s41598-021-99674-2

36. Ishizuka T, Nishida N, Homma Y, Hirayama T, Ishida Y, Kakizaki F, et al. Instantaneous changes in respiratory function induced by passive pelvic suspension in the supine position in relation to increased diaphragm excursion. J Phys Ther Sci. 2017;29(3):432-7. doi: 10.1589/jpts.29.432